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FINE STRUCTURE IN SUNSPOTS: SIZES, LIFETIMES, MOTIONS, AND TEMPORAL VARIATIONS

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Abstract. The analysis of a 4 1/2 hour series of high resolution white light observations of the umbra in a sunspot NOAA 7519 is described. An object-tracking procedure was applied to the destretched movie of 360 frames. In total, 662 umbral dots were tracked and their intensity variations, effective diameters, lifetimes, and proper motions were measured.

Key words: Sun: sunspots

1. Observations, Data Reduction, and Analysis Procedures

The observations (Simon et al. 1994) were taken on 5 June 1993 with the Swedish Vacuum Tower Telescope (aperture 50 cm) at La Palma, Canary Islands. A Kodak Megaplug Model 1.4 CCD camera was used to sample white light solar images at $\lambda 4680 \pm 50 \text{ \AA}$. The image scale was $0''.125/\text{pix}$. A "frame selection" scheme selected two best frames from intervals of 15 s duration; storing these onto Exabyte tape took 6 s, such that a total cycle time of 21 s was achieved. Due to image rotation during the 11 hr time series, the sunspot (NOAA 7519) was visible only for 4 hr 26 minutes, from 9:54 to 14:20 UT, during which we obtained 760 frames. All frames were registered, corrected for instrumental profile, and destretched to minimize seeing distortions. We selected 360 frames with rms granulation contrast higher than 7%, covering almost regularly the whole time period, for analysis. The selected frames were interpolated in time to obtain a constant time lag of 44.5 sec between successive frames.

For further analysis we selected a $8''.75 \times 8''.75$ (70×70 pixel) field covering the large central umbral core of the sunspot. Umbral dots (UDs) were isolated separately in each frame of the umbral core using an image segmentation method, based on an edge enhancement algorithm. This produced a segmented image in which the bright peaks (UDs) conserved their original intensity, and the background was set to zero. To identify and track UD in time, we developed a procedure which detected all the pixels forming an object (UD) in the segmented frame, and then investigated the spatial coincidences of objects in each two subsequent frames. Two objects were identified as predecessor/successor if they coincided in coordinates of at least one pixel in both frames. Formation, death, splitting, and merging of objects was taken into account. From the procedure described above, we obtained the lifetimes, intensities, effective diameters, and positions of 662 UD during their evolution. The average proper motion velocities were calculated from the positions by means of least-squares linear fits (cf. Molowny-Horas 1994).

2. Results

Temporal intensity variations. With power spectra we analyzed the temporal intensity variations of the 5 longest-lived UD (lifetime > 126 minutes). They show enhancements of power at periods of 32, 16, 8.5, 7.2, 6.1, 3.4, and 3.0 minutes.

Effective diameters. To obtain a histogram of the effective diameters d_{eff} of UD (Fig. 1) we utilized 11758 observations of instantaneous sizes of UD disregarding the temporal evolution. The values presented here correspond to the "observed sizes", which are influenced by image blurring. We can conclude that UD do not have a "typical" size. Their number rapidly increases with decreasing diameter down to the resolution limit.

Lifetimes. The histogram of the lifetimes is shown in Fig. 1. The number of UD rapidly decreases with increasing lifetime. We can conclude that UD do not have a "typical" lifetime. Short-lived UD (lifetimes below 10 minutes) represent about 2/3 of the population, while only 1% live more than 2 hours.

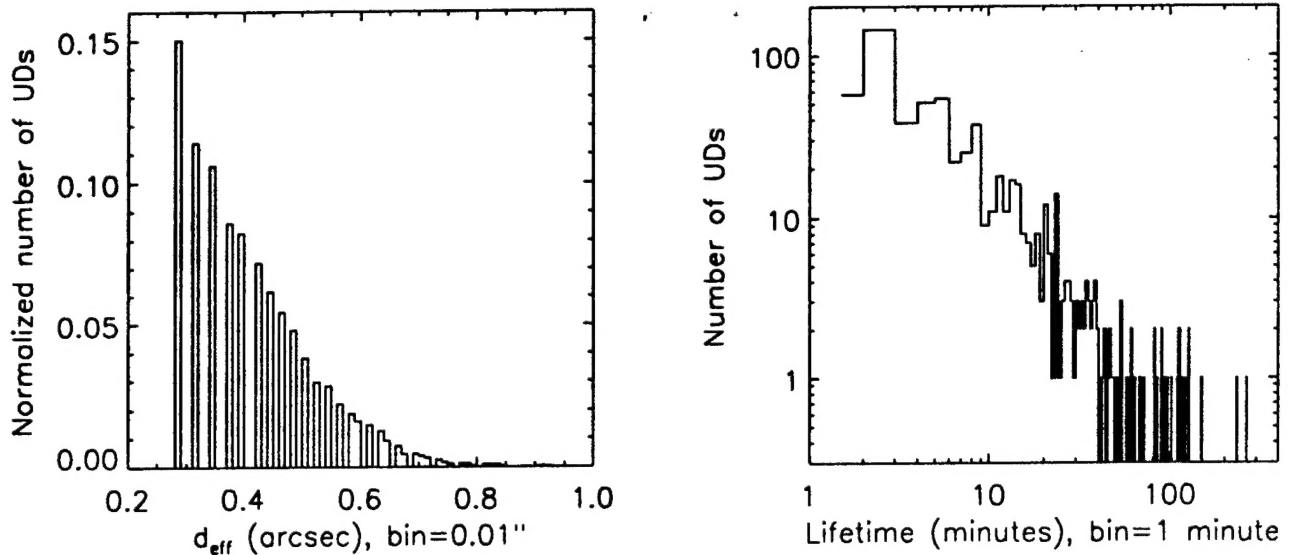


Figure 1. Left: Normalized number of UD vs. observed effective diameters d_{eff} for 11758 instantaneous measurements. Right: Number of UD vs. lifetime for 662 UD.

Spatial distribution. Large (diameter $> 0''.4$) and long-lived (lifetime > 10 minutes) UD appear mostly in regions with enhanced umbral diffuse background intensity.

Proper motions. The number of UD decreases with increasing magnitude of the proper motion velocity. Typical values of this velocity are 100 and 400 m/s. According to Ewell (1992), who distinguished between “central” and “peripheral” UD on the basis of their proper motions, we would expect a substantial concentration of rapidly moving “peripheral” UD near the umbral border. This effect, however, is not observed. Although moving UD with lifetimes > 10 minutes appear more frequently in the outer regions of the umbra, in general moving and stationary UD can be found at the periphery as well as in the central part. Thus velocity does not appear to be a good criterion for separating UD into “peripheral” and “central” UD.

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